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CONSTRAINING THE ACCRETION FLOW IN SGR A* BY GR DYNAMICAL AND RADIATIVE MODELING

Roman V. Shcherbakov[1], Robert F. Penna[1]

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ABSTRACT

We present the combination of dynamical accretion model based on 3D GRMHD simulations and general relativistic (GR) polarized radiative transfer. We write down the formalism of and perform the GR ray-tracing of cyclo-synchrotron radiation through the model of accretion flow in Sagittarius A*. GR polarimetric imaging is presented as well as the results for spectrum for a probable set of spins and orientations. Precise fitting formulae for Faraday rotation and Faraday conversion coefficients are employed for thermal plasma. The axisymmetic flow pattern and the magnetic field geometry correspond to averaged 3D GRMHD simulations near the black hole, whereas the analytic model was used far from the black hole. The density scaling is found by fitting the sub-mm flux. Spin $a = 0.7$ and inclination angle $\theta = 0.6$ produce the best fit to sub-mm flux and linear polarization fraction.

Subject headings:

1. GR POLARIZED RADIATIVE TRANSFER AND DYNAMICS

We come up with the formalism in several stages. First, we write down the standard propagation equations of Stokes parameters I, Q, U, V in the uniform thermal plasma (Melrose & McPhedran 1991) in a locally flat co-moving reference frame with synchrotron emissivities/absorptivities from Melrose (1971). We take Faraday rotation/conversion coefficients from Shcherbakov (2008), as the other published derivation of Faraday conversion coefficients (Huang et al. 2009) is a very crude approximation. Second, we parallel propagate the basis vectors along the null geodesic from the observer's plane to account for GR rotation of the basis. Third, with proper gauges on wave vector potential we write down the covariant equations of polarized radiative transfer. Following Huang et al. (2009), we assume that the matrix of absorptivities and propagation coefficients generalizes in the polarized transfer analogously to the unpolarized case.

The dynamical model used in the transfer starts with adiabatic 3D GRMHD simulations of thick accretion flow onto the Kerr black hole (BH) with spins $a = 0$, 0.7, 0.9, 0.98. We average the flow velocity, magnetic field, RMS magnetic field, gas density and pressure for the quasi-steady period of the developed accretion and separate the electron temperature T_e from the proton temperature T_p by applying the heating prescription from Sharma et al. (2007). The dynamical model is smoothly extended to large radii $r > 24M$ to take into account the Faraday rotation effect at large distances from the BH.

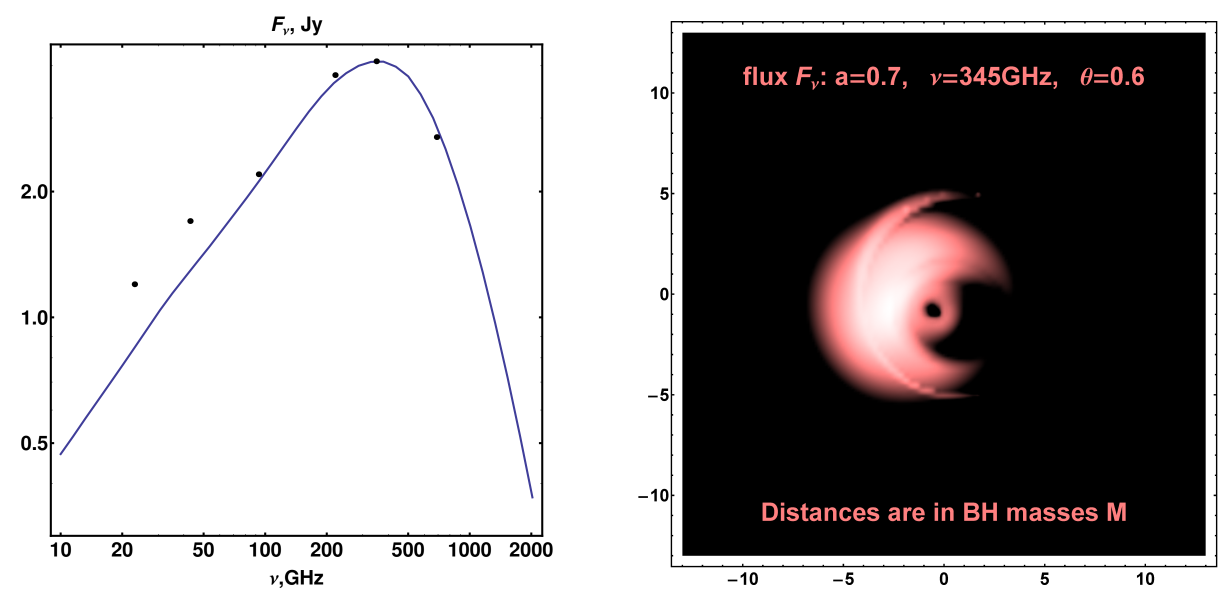

Fig. 1.— Specific flux F_ν in comparison to observations (Yuan, Quataert & Narayan 2004; Marrone 2007) (dots) on the left panel. Image of specific flux F_ν in logarithmic scale with contrast 8 at $\nu = 345$ GHz on the right panel. In both calculations spin $a = 0.7$, inclination angle $\theta = 0.6$.

[1] Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

2. RESULTS

We perform the GR polarized radiative transfer for each spin for a set of inclination angles θ and compare the specific fluxes, linear polarization fractions (LP), and circular polarization fractions (CP) to observations. We find, that the extreme spins $a=0.9$, $a=0.98$ do not fit all the observations well. They require lower density $n<2\cdot10^6$ cm^{-3} near BH to fit the flux at 220 GHz, but Faraday depolarization fails at these densities leading to high LP at 86 GHz compared to the observed value (Macquart et al. 2006). The preferred value of the inclination angle $\theta=0.6$ is coincident with that in Huang et al. (2009). The spin value $a=0.7$ gives the best fit (see Fig. 1), though spin $a=0$ produces good fits as well. Imaging produces some unexpected results. As our simulation appears to be substantially sub-Keplerian and have significant thermal support, the Innermost Stable Circular Orbit (ISCO) loses its importance and the black hole shadow is not always seen.

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